Asymmetry of pictorial space: A cultural phenomenon

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Art experts have argued that the mirror reversal of pictorial artworks produces an alteration of their spatial content. However, this putative asymmetry of the pictorial space remains to be empirically proved and causally explained. Here, we address these issues with the "corridor illusion," a size illusion triggered by the pictorial space of a receding corridor. We show that mirror-reversed corridors—receding respectively leftward and rightward—induce markedly different illusion strengths and thus convey distinct pictorial spaces. Remarkably, the illusion is stronger with the rightward corridor among native left-to-right readers (French participants, $n = 40$ males) but conversely stronger with the leftward corridor among native right-to-left readers (Syrian participants, $n = 40$ males). Together, these results demonstrate an asymmetry of the pictorial space and point to our reading/writing habits as a major cause of this phenomenon.

Introduction

Geometrically, mirror-reversed pictures differ solely by their opposite lateral organization. Phenomenologically, however, both their esthetic and perceptual properties might be modified well beyond this simple left-right inversion, as first pointed out by art experts (e.g., Gaffron, 1950; Wolfflin, 1941). The existence of aesthetic differences has been largely confirmed experimentally: Among pairs of mirror-reversed asymmetric

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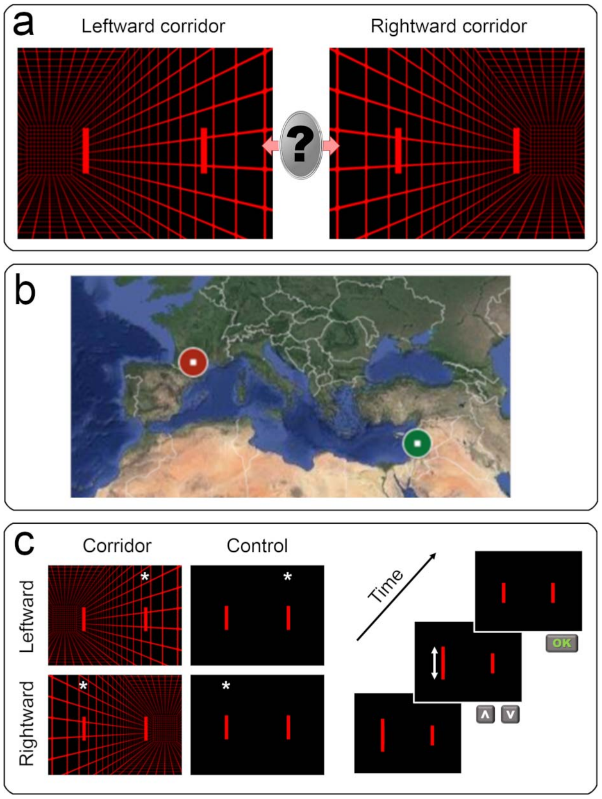

Figure 1. Stimuli and experimental design. (a) Mirror-reversed versions of the corridor illusion used in the present study. (b) Geographical origin of the French ($n = 40$; in red) and Syrian ($n = 40$; in green) participants (from GoogleMyMaps; cartographic data: INEGI Imagerie and NASA, TerraMetrics). (c) Experimental design. The four experimental conditions include the two mirror versions of the corridor and two controls without background, for correcting potential response biases. The white asterisks indicate the test bars. Each trial starts with the monocular presentation of the test and target bars, in one of the four experimental conditions described above. Participants use the "up" and "down" keys of the computer keyboard to adjust the size of the test bar to match the screen size of the target bar. Once the adjustment is achieved, participants press the space bar to initiate the next trial.

pictures, native left-to-right readers generally prefer the versions lit from the left (Hutchison, Thomas, & Elias, 2011; Sun & Perona, 1998) and portraying elements with rightward positioning and directionality (Beaumont, 1985; Levy, 1976). This aesthetic asymmetry holds a cultural dimension. Native right-to-left readers often exhibit reduced or opposite preferences thought to echo the opposite directionality of their reading/writing systems (Chokron & De Agostini, 2000; Ishii, Okubo, Nicholls, & Imai, 2011; Nachson, Argaman, & Luria, 1999; Smith & Elias, 2013).

In contrast to the aesthetic dimension, the perceptual one remains largely unexplored. Yet, art experts frequently advocated that mirror-reversal causes perceptual alterations, particularly in the spatial domain (see Gross & Bornstein, 1978 for review). According to Mercedes Gaffron (1950), native left-to-right readers naturally dive into pictures from their lower-left foreground to their upper-right background, so that those portraying elements organized along this path are more prone to evoke pictorial space than their reversed versions. Specific forms of visuospatial asymmetry have been documented, notably with regard to the apparent nearness (Adair & Bartley, 1958) or center (Bowers & Heilman, 1980) of portrayed elements. However, these results do not necessarily imply an asymmetry of the pictorial space, nor do they agree on the contribution of the reading/writing system (Chokron & Imbert, 1993; Ishii et al., 2011).

To address these questions, we exploit the fact that pictorial space triggers size-distance scaling; i.e., the perceived size of portrayed elements increases automatically with their apparent distance. The "corridor illusion" (Gibson, 1950) provides a compelling illustration: An element in the background of a pictorially-defined corridor is perceived larger than the same one positioned in its foreground. The strength of the illusory size difference reflects the amount of pictorial space conveyed by the corridor. As such, this illusion allows addressing the assertion of Gaffron by testing whether native left-to-right readers experience greater illusion strength (and thus more pictorial space) with a corridor receding rightward (left-foreground/right-background) than with its mirror image receding leftward (right-foreground/left-background; Figure 1a). It also allows questioning the role of the reading/writing direction in this potential asymmetry of the pictorial space by testing whether native right-to-left readers exhibit an opposite difference in illusion strength.

Method

Populations

Our study involves 80 participants divided into two populations (Figure 1b): a population of 40 native left-to-right readers (French participants: red symbol in Figure 2b; 18–31 years old, mean age = 23.8) and another one of 40 native right-to-left readers (Syrians participants recruited in Lebanon: green symbol in Figure 2b; 18–27 years old, mean age = 21.6). We intended recruiting as many unilingual Syrian participants as possible during our limited stay in Lebanon, and we then recruited an equal number of French participants. All participants had normal (or corrected-to-normal) vision and declared no history of neurological or psychiatric illnesses. In accordance with the

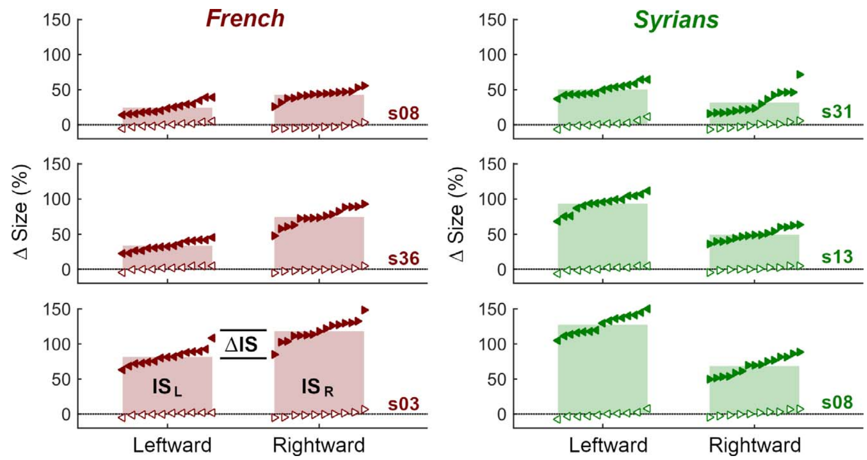

Figure 2. Results of the size adjustment task in French and Syrian participants. Behavioral responses are expressed as percentages of size difference between the adjusted test bar and the target bar. Responses are shown as sorted triangular symbols for the leftward and rightward corridors (filled symbols) and for their respective control conditions (opened symbols). The difference of mean response between the corridor and control conditions reflects the illusion strength, estimated separately for the leftward (IS_L) and rightward (IS_R) corridors. Their subtraction ($IS_R - IS_L$) gives the difference in illusion strength (ΔIS).

Helsinki Declaration, they signed an informed consent form prior to the start of the experiment and received monetary compensation for their involvement. Both populations attended school for 15 years on average (minimum–maximum = 7–23 years). They were composed uniquely of men, because of the difficulty encountered in recruiting Syrian women, who were generally reluctant of being involved in an experimental protocol. For avoiding gender bias, we therefore recruited only men in the French population. For each participant, we first administered a questionnaire for apprehending the degree of exposition to leftward and rightward reading/writing systems (~5 min), followed by a behavioral size adjustment task (~15 min). The measures took place under field conditions, because we could not offer a laboratory environment to our Syrian population. These latter carried out the experiment in the back of a car with tinted windows, while the French participants did it in a room of the Central Library at the Toulouse University.

Language questionnaire

To question the link between a putative laterality of the pictorial space and the reading/writing habits of the participants, we intended recruiting participants exposed solely to rightward (French) or leftward (Arabic) systems. We assessed the participants' exposition to languages of opposite directionality through French and Arabic versions of the Bilingual Language Profile (BLP) questionnaire available online (Birdsong et al., https://sites.la.utexas.edu/bilingual/). This questionnaire quantifies the level of expertise to various languages by covering a number of topics including "language history" or "linguistic attitudes" which are synthesized into a score ranging from 0 to 218 for each language. The results obtained when contrasting the scores for left-to-right versus right-to-left languages were close to maximum in both populations (207.8 ± 1.8 for the French and 204.3 ± 3.2 for the Syrians), indicating that our French and Syrian populations are almost exclusively using rightward and leftward writing/reading systems, respectively.

Psychophysical task

Participants performed the size adjustment task implemented with the EventIDE software (OkazoLab) on a laptop computer (hp probook equipped with a Core i5 processor and running Windows7; screen diagonal length: 39.6 cm; resolution: 1366 × 768 pixels). We positioned the screen of the laptop computer about 70 cm from our participants, who wore an occluding patch in front of the nondominant eye in order to discard binocular depth cues (stereopsis) and to potentiate monocular depth cues (the linear perspective of the pictorially defined corridor). Figure 1c presents the four experimental conditions which were pseudorandomly interleaved across trials: two with a corridor receding either leftward or rightward in the background ("corridor" conditions; 15 repetitions each) and two with a black background ("control" conditions; 10 repetitions each). The control conditions served as baselines for correcting potential response biases unrelated to the corridor illusion. Each trial started with the presentation of a pair of unequally sized vertical bars on top of the background, in the left and right parts of the screen (height: 191 to 239 pixels,

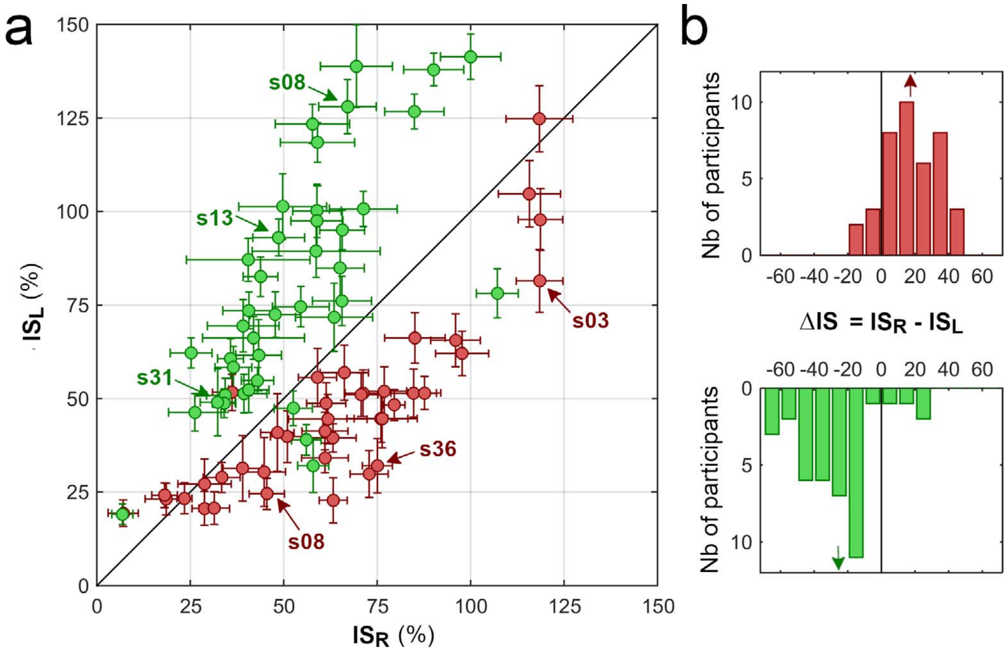

Figure 3. Strength of the corridor illusion in French and Syrian populations. (a) Distribution of mean illusion strength for the rightward (IS_R) and leftward (IS_L) corridors among all the French (in red) and Syrian (in green) participants. Error bars indicate the 95% CI. The arrows indicate the participants shown in Figure 2. (b) Frequency distribution histograms of the difference in illusion strength between the rightward and leftward corridors ($\Delta IS = IS_R - IS_L$) for the French (upper row) and Syrian (lower row) populations. The arrows indicate the populations' mean ΔIS.

width: 13 pixels). The participants used the up/down arrows on the keyboard to adjust the height of one the bars (test bar) to that of the other bar (target bar). They could freely explore the stimuli during the adjustment, without time constraint. Once satisfied by their adjustment, the participants pressed the space bar to validate their answer and to launch a new trial. Allowing an active exploration of the stimuli during the adjustment task rules out the possibility of biased responses due to the retinal blind spot.

Results

Figure 2 presents the results of the size adjustment task for exemplar French (left column, in red) and Syrian (right column, in green) participants. We quantified each behavioral response (triangular symbols) as the percentage of size difference (Δ size) between the test and target bars after adjustment (0% representing a perfectly adjusted size). For both the leftward- and rightward-receding corridors, the illusion strength (IS) is then quantified as the difference in mean response between the corridor condition (filled symbols) and its related control (i.e., the one with similar positioning of the test and target bars; opened symbols). It can be noted from these examples that the IS varies greatly among the participants, from moderate (upper row) to strong (lower row). Importantly, the IS also exhibits marked variations between the rightward (IS_R) and leftward (IS_L) corridors for each participant. Among the French exemplars, the rightward corridor evokes consistently greater IS: $IS_R > IS_L$; two-sample *t* tests; for s08, $t(28) = 7.1$, $p < 1\,0^{-7}$; for s36:3, $t(28) = 11.1$, $p < 10^{-11}$; for s03, $t(28) = 7.6$, $p < 10^{-7}$. By contrast, for the Syrian exemplars, the leftward corridor is more efficient: $IS_L > IS_R$; for s31, $t(28) = -4.1$, $p < 10^{-3}$; for s13, $t(28) = -11.2$, $p < 10^{-11}$; for s08, $t(28) = -12.3$, $p < 10^{-12}$.

As shown in Figure 3a, this tendency is fully confirmed by plotting the mean IS (and 95% CI) evoked by the rightward versus leftward corridors for the whole populations of French (in red) and Syrian (in green) participants. It can be observed that the French and Syrian participants exhibit nearly symmetrical distributions relative to the identity diagonal, with most Syrians above the diagonal ($IS_L > IS_R$) and most French below the diagonal ($IS_R > IS_L$). This is traduced by asymmetric distributions for the differences in illusion strength ($\Delta IS = IS_R - IS_R$) shown in Figure 3b. On average, the size illusion is 17.2% ± 15.2% (mean ± standard deviation) stronger with the rightward corridor among the French participants and 26.1% ± 22.3% stronger with the leftward corridor among the Syrian participants. We performed a mixed analyze of variance with the nationality (French/Syrian) as between-subject factor and the receding direction of the corridor (rightward/leftward) as within-subject factor. Results indicate that both factors are marginally significant on their own: The Syrians are slightly more sensitive to the corridor illusion than the French, $F(1, 78) = 4.3$; $p < 0.05$; $\eta^2 = 5.2\%$ of explained variance; and, consequently, the leftward corridor is slightly more efficient than the rightward one, $F(1, 78) = 4.4$; $p < 0.05$; $\eta^2 = 2.4\%$ of explained variance. However, these effects are comparatively marginal with regard to the highly significant interaction term, $F(1, 78) = 103.1$; $p < 10^{-15}$; $\eta^2 = 55.6\%$ of explained variance, which reflects the stronger illusory power of the rightward corridor in the French population and of the leftward corridor in the Syrian population.

Discussion

Our results show that the corridor illusion is sensitive to left-right inversion and thus that the pictorial space differs between a mirror pair of rightward and leftward corridors. This clear-cut empirical finding confirms the observations of art experts regarding the asymmetry of the pictorial space (Gross & Bornstein, 1978). We found that the rightward corridor evokes stronger illusion in our French population, validating the assertion of Gaffron (1950) about the greater pictorial space conveyed by pictures with left-foreground/right-background in native left-to-right readers. Finally, our finding that the Syrian population has an opposite asymmetry strongly suggests a cultural origin linked to the directionality of the reading/writing system.

Writing/reading habits had already been shown to affect our esthetic preferences for pictures (Chokron & De Agostini 2000; Ishii et al. 2011; Nachson et al., 1999; Smith & Elias 2013), but their role in the perceptual domain remained controverted (Chokron & Imbert, 1993; Ishii et al., 2011). Contrary to those previous studies, our approach addresses pictorial space through its scaling effect on the perceived sizes (Boring, 1964; Gibson, 1950). This process being both automatic and hidden to the participants (involved in a size adjustment task), it offers a unique opportunity for quantifying the impact of pictures' mirror-reversal in a perceptual domain while preventing potential contaminations by cognitive and esthetic biases. Although most previous studies also compared populations of native left-to-right and right-to-left readers, many of them did not control for the generally stronger exposure of native right-to-left readers to left-to-right languages (English or other Western languages). By testing an educated refugee population from the Syrian countryside, with very little exposure to Western languages (as attested by our language questionnaire), we have been able to control for this often-omitted bias.

The interindividual variability we observed in the overall illusion strength (e.g., Figure 2) is a well-known phenomenon (Koenderink, van Doorn, & Kappers, 2005). It could partly relate to differences in the functional organization of the primary visual area (Schwarzkopf, Song, & Rees, 2011), in which a correlate of the corridor illusion was first described (Murray, Boyaci, & Kersten, 2006). Nevertheless, the intraindividual and culture-dependent variability documented here for the corridor illusion can be explained neither by this biological factor, nor by any other interindividual and culture-independent factor classically put forward in lateralized perceptual processes (e.g., handedness, functional differences between the cerebral hemispheres).

An objection that could be raised is that beyond the directionality of their reading/writing systems, our French and Syrian populations have other cultural differences, which could potentially account for the results presented here. Although we cannot firmly reject this alternative explanation, we could not identify other cultural factors with opposite left-right directionality between these populations. A decisive step forward might be to test populations exposed to both left-to-right and right-to-left languages. Our prediction is that the asymmetry of pictorial space should decrease as people have more balanced exposure to languages with opposite directionality.

Overall, we show that the ability to extract pictorial space, which emerges during the first months of infancy (Kavšek, Yonas, & Granrud, 2012) and is shared by many other animal species (Barbet & Fagot, 2002; Cavoto & Cook, 2006; Timney & Keil, 1996) can nevertheless be profoundly influenced by the subsequent acquisition of literacy.

Keywords: pictorial space, reading/writing habits, spatial cognition, culture

Acknowledgments

S. Rima and J.-B. Durand developed the study concept. All authors contributed to the study design. S. Rima and C. Khalil did the testing and data collection. S. Rima and J.-B. Durand performed the data analysis and interpretation under the supervision of B.R. Cottereau and Y. Trotter. J.-B. Durand drafted the manuscript, and S. Rima; B.R. Cottereau and Y. Trotter provided critical revisions. All authors approved the final version of the manuscript for submission.

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